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Airway reactivity in response to repeated emotional film clip presentation in asthma.

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Abstract

Emotional stimuli elicit airway constriction in individuals with asthma and in healthy individals, but little is known about effects of repeated stimulation. We therefore explored the effect of repeated emotion induction on respiratory resistance (R_{rs}) using unpleasant, high-arousal surgery films and investigated effects of respiration and emotional reactivity. Twenty-six participants (13 with asthma) watched a series of 12 short, 45-s surgery films followed by 2-min recovery periods. R_{rs} assessed with impulse oscillometry was significantly elevated during films in both groups compared to baseline and recovered quickly after that. No habituation of airway responses ocurred. R_{rs} was higher in participants who felt more aroused and less in control when watching the films. Changes in R_{rs} remained significant when controlling for changes in respiration or emotional experience. Thus, although unpleasant stimuli lead to elevated R_{rs}, airway obstruction is not exacerbated with repeated stimulation due to a fast return to baseline after stimulation.

Keywords: emotion; asthma; respiratory resistance; respiration; habituation; impulse oscillometry; lung function

Introduction

Stress and negative affect contribute to the development and maintenance of asthma morbidity through a variety of mechanisms (Ritz et al., 2013). Stress and negative emotions have been shown to impact airway pathophysiology, including changes in inflammatory status and airway hypersensitivity (for review, see Marshall, 2004; Chen & Miller, 2007; Trueba & Ritz, 2013), which make the airways more sensitive to a variety of asthma triggers. Moreover, stress and negative emotions can be asthma triggers in their own right, as they can elicit increased contraction of airway smooth muscles, leading to emotion-induced airway constriction (Ritz, 2012). In individuals with asthma, the degree of emotion-induced airway constriction correlates with self-report of psychological triggers of asthma in daily life, suggesting that it is one of the major drivers for psychologically triggered asthma (Ritz et al., 2006).

Induction of stress and negative emotions has an extensive history as a laboratory-based model of stress-induced airway constriction (Kotses et al., 1987; Levenson, 1979; Ritz and Steptoe, 2000). Using film clips or still images, these studies have consistently shown reactivity of the airways to materials that are high in arousal and negative valence, whereas studies that have used other stress-induction methods, such as mental arithmetic have shown less consistent effects on airway reactivity (for an overview, see Ritz, 2012). It has been hypothesized that stressors that elicit a passive coping responses (such as unpleasant film materials) as compared to elicitors of active coping responses (such as achievement-oriented challenges) may be more detrimental to the airways due to their association with cholinergic excitation that leads to airway constriction (Lehrer, 1998). The involvement of the cholinergic system in emotion-induced airway responses is further corroborated by a reduction of emotion-induced airway reactivity after inhalation of ipratropium bromide vs. a placebo substance (Ritz et al., 2010b). Alternative mechanisms have been proposed, including bronchoconstriction due to changes in breathing

response similar to the bronchoconstrictive effects of exercise or normocapnic hyperventilation. However, previous studies have not found clear evidence for this proposed pathway (Ritz, 2012).

Emotion-induced airway constriction has been observed in individuals with asthma as well as in healthy control participants, although a larger effect has been observed in individuals with asthma compared to healthy controls (Ritz, 2012). Effects of allergic states on cholinergic neural signaling have been suggested as mechanisms explaining these differences in reactivity (Undem and Taylor-Clark, 2014). In individuals with asthma, these differences may furthermore occur during states in which the airways are already compromised, further adding to bronchoconstriction that is caused through other triggers or mechanisms or complications in asthma management (Janssens and Ritz, 2013).

Studies on emotion-induced airway reactivity have given only limited attention to the time course of changes in airway responses. Two exception can be found in the literature: one of the first studies on emotion-induced airway reactivity in asthma showed that airway obstruction increased during particularly arousing parts of negative film clips (Levenson, 1979). Furthermore, a recent study showed that during 4-5 min film clips the initial increase in respiratory impedance wears off after reaching a peak 1-2 min into the film clip (Ritz et al., 2012).

So far, no studies have investigated the effects of repeated emotional stimulation on emotion-induced airway reactivity. Changes in airway reactivity in response to a repeated stressor may inform us about the mechanisms of emotion-induced airway reactivity. A first possibility is that over time, changes in emotional reactivity will occur, as participants habituate to the emotional content of the film clips or find different ways to cope with the emotional content of the film clips. Another possibility is that changes in airway reactivity occur irrespective of changes in emotional experience of the films, either due to habituation of physiological reactivity or due to changes in airway physiology that are related to (active) changes in breathing behavior. Yet another possibility could be a sensitization with increasingly

stronger airway responses or an accumulation of constriction leading to sustained and/or enhanced airway obstruction. The occurrence of changes on these different levels would have different implications for the management of asthma.

Information about changes in airway reactivity over time also has practical implications for further studies on emotion-induced airway reactivity, especially if reactivity is dependent upon repeated presentation of stimuli. For example, functional Magnetic Resonance Imaging (fMRI) studies on brain correlates of emotion-induced airway reactivity may benefit from accurate information about a decline in reactivity over repeated presentations of stimulus material, in order to maximize effect sizes of the effects that are under investigation. Additionally, with studies increasingly indicating a role for the small airways in asthma (Takeda et al., 2009; van den Berge, ten Hacken, Cohen, Douma, & Postma, 2011), we were interested in further studying differences in central versus peripheral airway response to repeated stimulus presentation. The multiple frequency forced oscillation technique has been used to identify small airway complications and we utilized a version of this technique, impulse oscillometry (Smith, Reinhold, & Goldman, 2005), for this purpose.

In this study, our aims were to investigate the effect of repeated presentation of short emotional film clips on changes in central and peripheral airway reactivity in individuals with asthma, and to explore if changes in emotional reactivity or breathing behavior contribute to these changes in respiratory resistance. In line with previous research, we expected a greater impact of emotional film clips in individuals with asthma compared to control participants. We held no specific hypotheses regarding the pattern of habituation versus sensitization of airway reactivity during repeated film clip presentation, but expected that, if changes were observed at all, they would more likely indicate habituation, similar to earlier work that found habituation during longer presentations of emotional films (Ritz et al., 2012).

Methods

Participants

Participants were undergraduate students or members of the greater university community. They participated in exchange for extra course credit or monetary compensation ($35). Potential participants were pre-screened prior to participation: Inclusion criteria were a self-reported physician confirmed diagnosis of asthma (asthma group), or an absence of any lung disease (control group). Furthermore, inclusion criteria were non-smoking status for at least 6 months and a lifetime smoking history of less than 6 pack-years. They had stable mental and physical health, with no reported history of cardiovascular disease, diabetes, neurological or endocrine disorders; no indications of a history of mania, psychosis, no current indications of depression or substance abuse. Furthermore, participants were excluded if there were indications of blood, injury, or injection phobia. The SMU Institutional Review Board approved the study, and written informed consent was gathered from all participants.

Prior to participation, participants were instructed to continue inhaled corticosteroid use as usual, but to discontinue short-acting bronchodilator use for 6 h, long-acting beta-agonist use for 12 h, antihistamines for 24 h, and leukotriene inhibitors for 3 days prior to participation. Participants were also asked not to eat or drink anything (except water) for one hour prior to their appointment (except for either a power bar, granola bar, or candy bar).

Materials & Measures

Surgery film clips were short 45-s film clips taken from videos depicting close ups of different surgical procedures (7 heart surgery, 3 foot surgery, 2 stent graft). The use of surgery films was based on previous success of this type of film to elicit sustained increases in respiratory resistance (R_{rs}) (Ritz et al.,

2012). The 12 film clips were selected based on pilot data showing similar levels of arousal and unpleasantness across the individual film clips (film clips are available upon request).

R_{rs} was measured using impulse oscillometry (IOS MasterScreen, Jaeger, Hoechberg, Germany) (Goldman et al., 2002; Meraz et al., 2011). The pneumotachograph of the device was calibrated daily with a 3-liter syringe. The pneumotachograph was also used to perform spirometry (forced expiratory volume in 1s, FEV_1, was extracted as a variable of interest), as well as to extract measurements of tidal volume (V_T) and respiration rate (RR).

As a common indicator of airway inflammation we also determined by the fraction of exhaled nitric oxide (FeNO, in ppb) (Barnes et al., 2010; Dweik et al., 2011), using an electrochemical analyzer (NIOXmino; Aerocrine; Solna, Sweden).

Emotional valence (pleasant-unpleasant), arousal (excited-calm), and dominance (controlled-in control) was measured using the Self-Assessment Manikin (SAM) scales, which are nine point (1-9) pictorial rating scales (Bradley and Lang, 1994).

In addition, individuals with asthma completed the Asthma Control Test (Schatz et al., 2006), a 5-item questionnaire that is used to assess asthma control as an indicator of successful asthma management. Total scores range from 5-25, with a score of 25 indicating perfect control over manifestations of asthma, and scores of 20 or above indicating well-controlled asthma.

Procedure

Participants received verbal information about the experiment and read the consent form. After giving written informed consent, participants proceeded with filling out a questionnaire package. This was followed by baseline FeNO and impulse oscillometry tests.

Subsequently, participants were administered 4 trial blocks of films and recovery periods. Each trial block consisted of three 45-s surgery film clips, with each film clip followed by a 2-min recovery period. Impulse oscillometry was performed during surgery film clips and during the first 80 seconds of each recovery period. After each trial block, participants completed the rating scales that measured their affective state during the film clips retrospectively. Participants then performed a final measurement of impulse oscillometry, FeNO, and spirometry.

Data reduction and data analysis

Impulse oscillometry generated R_{rs} measures at different frequencies. Resistance at 5Hz (R_{rs5}) was extracted as a measure of overall airway resistance, resistance at 20Hz (R_{rs20}) as a measure of central airway resistance (Smith et al., 2005). Furthermore, because the difference between resistance at lower and higher frequencies increases with peripheral airway complications, the difference between these two measures (R_{rs5-20}, frequency dependence of resistance) was included as a measure of peripheral airway resistance (Duiverman et al., 1984; Grimby et al., 1968). Oscillometry output was visually inspected for swallowing artifacts and was averaged, resulting in a single value for each film clip and recovery period. RR, V_T, and minute ventilation ($V'_E = RR*V_T$) were extracted on a breath-by-breath basis and averaged, resulting in a single value for each film clip and recovery period. Data were analyzed using linear mixed models in order to control for the hierarchical structure of the dataset. Reactivity analyses (changes from baseline) were performed comparing the first trial in each block to baseline values using a Trial (3) x Group (2; asthma vs. control) X Clip/Baseline (2) linear mixed model. Changes between film clip and recovery periods were analyzed using Block (4) x Trial (3) x Clip/Recovery (2) x Group (2) linear mixed models. Models that tested the association of respiratory resistance with other respiratory parameters or affective experience (SAM rating scales) included these variables as time-varying predictors (TVPs). One set of models included V'_E, RR, and V_T, and a second set of models included

valence, arousal, and dominance as TVPs. Recent research (e.g., Wang and Maxwell, 2015) has shown that the values of a TVP represent two distinct components: a between-subjects component that represents the participant's average level of the TVP across all the time points, and a within-subjects component that represents the participant's deviation, at each time point, from his/her average level on the TVP. Thus, each TVP was disaggregated into these two components for the analyses including TVPs. All analyses were carried out using SPSS 22.

Post-hoc power analyses were conducted using the program PinT 2.12 (Snijders and Bosker, 1993), a power analysis program designed for 2 level linear mixed models. This program showed that we had greater than .95 power to detect a medium effect size for the least powerful interactions (those involving asthma) and an .87 power to detect a medium effect size for the within-subjects main effects.

Results

Baseline sample characteristics.

The sample consisted of 13 individuals with asthma and 13 control participants. Sample characteristics are listed in Table 1. On average, participants with asthma were older compared to the control group. Participant groups did not differ on sex, racial/ethnic background, or FEV_1. FeNO values were substantially higher in the group with asthma.

Table 1: Baseline Characteristics of Asthma Group and Control Group.

Variable	Asthma Group		Control Group			
	Mean	SD	Mean	SD	F (1,24)	p
FeNO (ppb)	55.6	67.0	16.3	8.3	7.30[1]	0.02
FEV_1 (l)	3.00	0.84	3.30	0.82	0.85	0.37
FEV_1 % predicted	91.1	16.6	87.5	11.9	0.41	0.53
R_{rs5} (kPa/l/s)	0.379	0.118	0.371	0.068	0.05	0.82
Age	32.8	13.9	19.8	1.01	11.26	0.001
Sex					χ^2	P
Female	10		8		0.73	0.394
Male	3		5			

Race/ethnicity				
African American	2	1	2.13	0.71
Asian	2	3		
Latino/Hispanic	2	3		
Non Latino White	6	6		
Other	1	0		

[1]F(1,17.17; Welch corrected) , based on ln(FeNO)

Respiratory resistance

Total respiratory resistance (R_{rs5}*)*

R_{rs5} was increased during film clips compared to baseline, $t(36)=3.19$, $p=.003$, and was higher during film presentation compared to recovery periods, $F(1,38)=72.2$, $p<.001$. The difference in elevation between asthma participants and control participants was not significant, $F(1,38)=2.45$, $p=.13$ (Figure 1). Furthermore, participants showed a tendency towards reduction in R_{rs5} across trial blocks, with a significant Group x Block interaction, $F(3,106)= 3.10$, $p= .030$, indicating that this decrease in resistance was greater for control participants compared to the group of asthma participants (Figure 2). There were no other significant effects.

Central airway resistance (R_{rs20}*)*

R_{rs20} did not increase during film clips compared to baseline, $t(39)=-0.63$, $p=.53$. However, R_{rs20} was elevated during film clip presentation compared to recovery periods, $F(1,43)= 92.9$, $p<.001$ (Figure 1). We also observed a significant decrease in resistance across trials within a trial block, $F(2,394)=6.01$, $p=.003$ (Figure 2). There were no other significant effects in this analysis.

Indicator of peripheral airway resistance (R_{rs5-20})

Frequency dependence of resistance as an indicator of the peripheral airway component increased from baseline to film clip presentation, $t(39)=4.69$, $p<.001$, and was elevated during film presentation compared to recovery, $F(1,47)= 24.6$, $p<.001$. This effect was further specified by a significant Clip/Recovery x Group interaction effect showing that the effect of film presentation on peripheral resistance was stronger for individuals with asthma compared to control participants, $F(1,47)= 7.16$, $p=.010$ (Figure 1). There were no other significant effects. However, the main effect showed a weak tendency for decreasing resistance across trials within a trial block, $F(2,319)= 2.29$, $p=.10$.

Respiration

V'_E changes from baseline to film clip presentation were not significant, $t(35)=-1.84$, $p=.075$. However, V'_E increased during recovery periods compared to film clip presentation, $F(1,79)=9.00$, $p=.004$, which was limited to individuals with asthma, $F(1,79)=5.19$, $p=.025$. Furthermore, there was a significant Block effect, $F(3,233)=4.70$, $p<.003$, and post hoc comparisons revealed that V'_E decreased especially during blocks 2 and 3, compared to block 1.

RR did not change from baseline to film clip presentation, $t(32)=-1.16$, $p=.26$, but increased across trial blocks, $F(3,184)=25.21$, $p<.001$. Furthermore, there was a significant Clip/Recovery x Group interaction, $F(1,42)=4.31$, $p=.044$, showing an increase in RR after film clip presentation in the control group whereas participants with asthma decreased their RR during recovery.

V_T was log-transformed due to skewness (1.8). V_T increases from baseline to film clip presentation were marginally significant, $t(33)=1.94$, $p=.060$. V_T decreased across trial blocks, $F(3,106)=417.4$, $p<.001$, and also across trials within blocks $F(2,237)=3.05$, $p=.049$. The decrease across trials was steeper for the control group compared to participants with asthma, $F(2,237)=3.31$, $p=.038$.

Adding respiratory parameters to the R_{rs} models did not result in effects of average (between-individual) levels of the respiratory parameters on R_{rs5} or $R_{rs20.}$ However, within-individual increases in V_T were associated with reductions in R_{rs5} and R_{rs20} , and within-individual-increases in V'_E were associated with increased R_{rs20} (cf. Table 2). When analyzing the effect of respiratory parameters on R_{rs5-20}, we found that participants with higher average V'_E (F(1,57)=10.92, p=.002) and lower average RR (F(1,58)=4.27, p=.043) showed higher levels of R_{rs5-20}, whereas we identified no effects of within-individual changes in respiratory parameters on R_{rs5-20}. Nevertheless, adding respiratory parameters as time-varying covariates to the R_{rs} models did not result in any substantial changes to previously identified significant effects.

Ratings of affect

Valence and arousal increased from baseline to film blocks, t(46)=9.18, p<.001 and t(27)=1.78, p=.086, respectively, whereas dominance remained unchanged. There were no significant changes of valence, arousal or dominance across blocks. However, participants with asthma rated film stimuli increasingly more unpleasant over blocks, whereas values for controls remained stable, F(4,56)= 2.54, p=.050. There were no other differences between groups in any of the affect ratings. When adding affect ratings to the models predicting R_{rs}, within-individual inreases in feelings of pleasantness (valence) were related to increases in R_{rs5-20} (cf. Table 2). For arousal, average (between-individual) ratings showed that more calm individuals showed higher R_{rs5} , R_{rs20} , and R_{rs5-20}, whereas within-individual increases in arousal were related to increases in resistance (cf. Table 2). Finally, individuals with lower average dominance ratings had higher R_{rs5} (F(1,82)=4.37, p=.040), and within-individual reductions in dominance were associated

with increased R_{rs5} and R_{rs5-20} (Table 2). Main results for R_{rs} measures were unchanged by adding these variables to the R_{rs} models[1].

Airway inflammation

FeNO was measured again at the end of the experiment, showing similar differences between participants with asthma (Mean: 55.62 ppb, SD: 62.83) and control participants (Mean: 16.69 ppb, SD: 7.10). This resulted in a main effect of Group across both timepoints (F(1,24)= 7.28, p=.013). However, However, we did not observe any significant pre-post differences , indicated by a nonsignificant main effect of Time (F(1,24)=1.48, p=.,236), and Time x Group interaction (F(1,24) =0.29, p=.597.

Table 2. Estimates of relationship between respiratory resistance and time-varying covariates (within-individuals)

Parameter	Estimate	SE	*df*	*t*	*p*
R_{rs5}					
V'_E	0.003	0.0016	593	1.68	.093
RR	-0.002	0.0012	593	-1.35	.179
$V_{T\ (ln\ transformed)}$	-0.044	0.0161	593	-2.77	.006
Valence	-0.003	0.0016	585	-1.69	.092
Arousal	-0.005	0.0016	590	-3.27	.001
Dominance	-0.004	0.0014	561	-2.76	.006

[1] Effects of dominance were further explored by adding baseline dominance as a moderator of Group (Asthma vs. Control) and Clip/Recovery effects (including their interaction) on R_{rs5} and R_{rs20}. However, these analyses did not result in significant (moderator) effects of baseline dominance (all *p*s>.323), and neither did the analysis that only included the Baseline dominance x Group interaction (*p*s>.310).

R_{rs20}					
V'_E	0.003	0.0012	592	2.63	.009
RR	-0.001	0.0009	592	-1.24	.217
$V_{T\ (ln\ transformed)}$	-0.055	0.0123	592	-4.49	< .001
Valence	0.002	0.0013	598	1.31	.191
Arousal	-0.004	0.0013	598	-2.71	.007
Dominance	-0.001	0.0011	598	-1.12	.263
R_{rs5-20}					
V'_E	-0.001	0.0012	519	-1.03	.302
RR	-0.000	0.0009	469	-0.28	.775
$V_{T\ (ln\ transformed)}$	0.014	0.0116	399	1.18	.237
Valence	-0.003	0.0012	574	-2.46	.014
Arousal	-0.003	0.0012	571	-2.78	.006
Dominance	-0.003	0.0011	525	-2.51	.012

Note: $V'_{E,}$ RR, and $V_{T\ (ln\ transformed)}$ were included in one set of models (which also included the Film Clip variables), and the SAM scales Valence, Arousal and Dominance were included in a second set of models; for the Valence scale, higher values indicate more negative affect, for the Arousal scale, high values indicate more calmness, and for the Dominance scale, higher values indicate greater feelings of being in control or dominant.

Discussion

Effects of unpleasant films on the airways

In this study we sought to examine the temporal course of airway obstruction changes due to repeated emotional stimulation in individuals with and without asthma. Aversive film presentations resulted in increased R_{rs} compared to baseline, and, to a stronger extent, compared to recovery periods, in both groups of individuals. We did not observe overall stronger effects of emotion-induced airway constriction in participants with asthma vs. control participants (Ritz et al., 2010b), only frequency dependence of resistance (R_{rs5-20}), a putative measure of resistance in the peripheral airways, showed such differences. Past emotion-induction studies have varied in the extent to which differences between asthma and health were shown (for review, see Ritz, 2012). A number of variables could account for that, including differences in sample size (and thus power) and severity level or control of asthma. Although airway constriction in asthma is mainly due to constriction of the central airways, small airway disease has recently gained importance as a marker of poorly controlled asthma and is an important contributor to dyspnea perception in asthma (Takeda et al., 2009; van den Berge et al., 2011). Our findings suggest that the effects of emotion-induced airway constriction are not limited to the central airways but may contribute to small airway dysfunction in individuals with asthma.

Changes in R_{rs} *over time*

During the experiment, we observed changes of emotion-induced R_{rs} over time. However, R_{rs5} and R_{rs20} showed different patterns of change: R_{rs20} decreased across trials within a block of films, whereas R_{rs5} decreased across trial blocks. These changes occurred during both film clip presentations as well as recovery periods, suggesting that they were unrelated to the phasic effects of emotion-induced airway constriction. The absence of changes over time in R_{rs} during film clips vs. recovery suggests that emotion-induced effects on R_{rs} do not habituate over time, nor are there accumulation effects due to

sensitization or lack of complete recovery. This observation is important for future research on emotion-induced airway constriction as it suggests that, despite possible decreases in tonic respiratory resistance, the effect of emotion-induced airway constriction is stable across repeated presentations of short emotional films. Furthermore, in experiments that are dependent on repeated trials, short presentations of film clips may be preferable to longer film clips, which have shown a habituation of emotion-induced airway constriction over the course of the film clips (Ritz et al., 2012).

Pathways of effects

Apart from changes in respiratory resistance, the presentation of surgery films also caused a change in respiration: in individuals with asthma, V'_E increased and RR decreased after film clip presentation, whereas in control participants, RR increased after film clip presentation. However, taking into account changes in respiration as time-varying predictors of resistance did not change any of our findings on airway responses to film clip exposure. Previous studies have shown inconsistent associations between emotion-induced changes in breathing behavior and emotion-induced airway constriction (Ritz et al., 2010b; Ritz et al., 2012; Ritz et al., 2011a), suggesting that changes in respiratory pattern cannot fully account for emotion-induced R_{rs} increases (Ritz, 2012). Nevertheless, within-individual increases in V'_E and V_T were associated with lower values in R_{rs20}, and it is not guaranteed that such respiration changes, if more pronounced with other stimulation material or modalities, would not affect central airway resistance changes more substantially. Therefore, and because of the observed changes in respiration, we still suggest taking parameters of respiratory pattern into account when conducting experiments with repeated measurements of respiratory resistance.

Multilevel analysis that included measures of affect as time-varying predictors of resistance showed that increases in perceived arousal and decreases in dominance predicted greater respiratory resistance.

These findings confirm the importance of arousal in emotion-induced airway constriction (see also Ritz et al., 2012). Furthermore, the association of low dominance (the feeling of not being in control) with higher R_{rs} is congruent with the assumed role of passive coping responses as a potential driver of emotion-induced airway constriction (Lehrer, 1998; Lehrer et al., 1996). In addition, in daily life situations of high negative affect, asthma patients showed stronger high-frequency heart rate variability (HF-HRV) changes suggestive of vagal activity and lower peak expiratory flow when they were also low in asthma self-efficacy (Campbell et al., 2006), which can be interpreted as a perceived lack of control over asthma and its treatment. Furthermore, in children with asthma suffering from depression, greater HF-HRV increases to a distressing film presentation have been shown to be associated with greater airway resistance measured after film clip presentation (Miller et al., 2009), being consistent with an interpretation linking helplessness or lack of control with increased vagal activation and increased airway resistance. Finally, pharmacological blockade of airway cholinergic receptors greatly reduces emotion-induced airway constriction (Ritz et al., 2010b). If these responses are linked to a perceived lack of control, as is suggested by our findings, this would open up possibilities for interventions that reduce emotion-induced airway constriction by enhancing feelings of control. Further research should explore causal pathways linking perceived control to airway obstruction and the possibility to intervene and identify specific target populations for this type of intervention.

Apart from perceived arousal and dominance, perceived valence was also associated with R_{rs}, but only for the measure of peripheral resistance. The direction of the association (greater pleasantness associated with greater peripheral resistance) did run counter to what has been found previously with measures of total and central respiratory resistance. However, associations of perceived affect with peripheral resistance measures have not been studied before. Furthermore, prior research has found effects of both high arousal positive affect and high arousal negative affect, although findings on positive affect have been less consistent compared to effects of negative affect (Ritz, 2012). Use of

unipolar valence scales could help to further disentangle the relationships between valence, arousal and airway resistance.

Finally, it is important to note that affective ratings did not fully account for the effect of film clip presentation on respiratory resistance. When including affect variables in the analyses, both the effects of film presentation as well as habituation effects and interactions with asthma remained significant. This is probably reflective of the typically low to moderate correlation between measures of self-report and physiology in psychophysiological research (Bradley and Lang, 2000). Additionally, self-reported affect was measured at a lower resolution (ratings for each trial block instead of individual film clips) and was measured retrospectively, which may have introduced bias to our rating data. Moreover, stability of affect ratings across trials blocks suggests that the decrease in R_{rs} across trial blocks was not due to changes in emotional reactivity across trial blocks.

Differences between participants with asthma and control participants

Contrary to our hypotheses, we did not observe consistent group differences between participants with asthma and control participants across all dependent variables. However, group membership did moderate the effects of film clip presentation on one of the resistance measures (R_{rs5-20}), showing greater differences between film clip and recovery periods in participants with asthma compared to control participants. Furthermore, participants with asthma showed a significant increase in V'_E and a decrease in RR during recovery periods compared to periods of film clip presentation, which did not occur (V'_E), or was reversed (RR) in control participants. The decrease in RR in asthma is reminiscent of other research that has also shown lengthening of the respiratory cycle or its components in response to stress in asthma (Ritz et al., 2011b). Thus, these findings may be suggestive of a specific respiratory response of individuals with asthma to the onset or offset of emotional stimuli. However, with regard to

potential influences on airway caliber, the lack of consistency across R_{rs} variables and the lack of correspondence with observations in other studies (Ritz, 2012; Ritz et al., 2012; Ritz et al., 2011b) warrants caution in the interpretation of the observed associations between the respiratory pattern and R_{rs}. Participants with asthma furthermore showed an increase in perceived unpleasantness and more sustained V_T response across film clip blocks. These findings, combined with the less steep decline in R_{rs5} across blocks in participants with asthma, could indicate a clinically relevant difference between i asthma and health in the persistence of emotion-induced airway changes in response to repeated emotional stimulation.

Limitations

A primary limitation of our experiment was that we only explored habituation of emotion-induced airway constriction in response to surgery film clips and did not include comparison film clips of other emotional qualities. Therefore, we are unable to determine with certainty whether our results are limited to the specific stimuli that were used in this experiment. However, other studies suggest a remarkable consistency in emotion-induced airway responses to a variety of high arousal negative stimuli (Ritz et al., 2010a; Ritz et al., 2011a). Nevertheless, it is not clear whether other presentation schedules, such as intermixed presentation of high-and low arousing film clips, would show similar habituation responses. Another limitation was our small sample size, although our repeated measures design increased power (as our post-hoc power analysis showed) and the use of sensitive mixed model analyses made up somewhat for this shortcoming. Finally, our sample was also demographically restricted, with a focus on the undergraduate student population. Although demographics have not previously shown to affect airway responses to emotion-induction, replication with larger and more representative samples is certainly desirable.

Conclusion

Our study shows that repeated stimulation of the airways with brief emotional film clip presentations leads to phasic increases of respiratory resistance without evidence for cumulative effects, nor for habituation of emotion-induced respiratory resistance changes. Changes in breathing behavior did not explain this reactivity characteristic. Our findings furthermore suggest a relationship between (changes) in self-reported affective response and R_{rs}, with the dominance dimension showing promise in predicting individual differences in airway obstruction. Future research with larger and more diverse samples utilizing longer lasting stimuli and combinations of psychological and other triggers are needed to further elucidate response characteristics of the airways to emotion and stress in health and disease.

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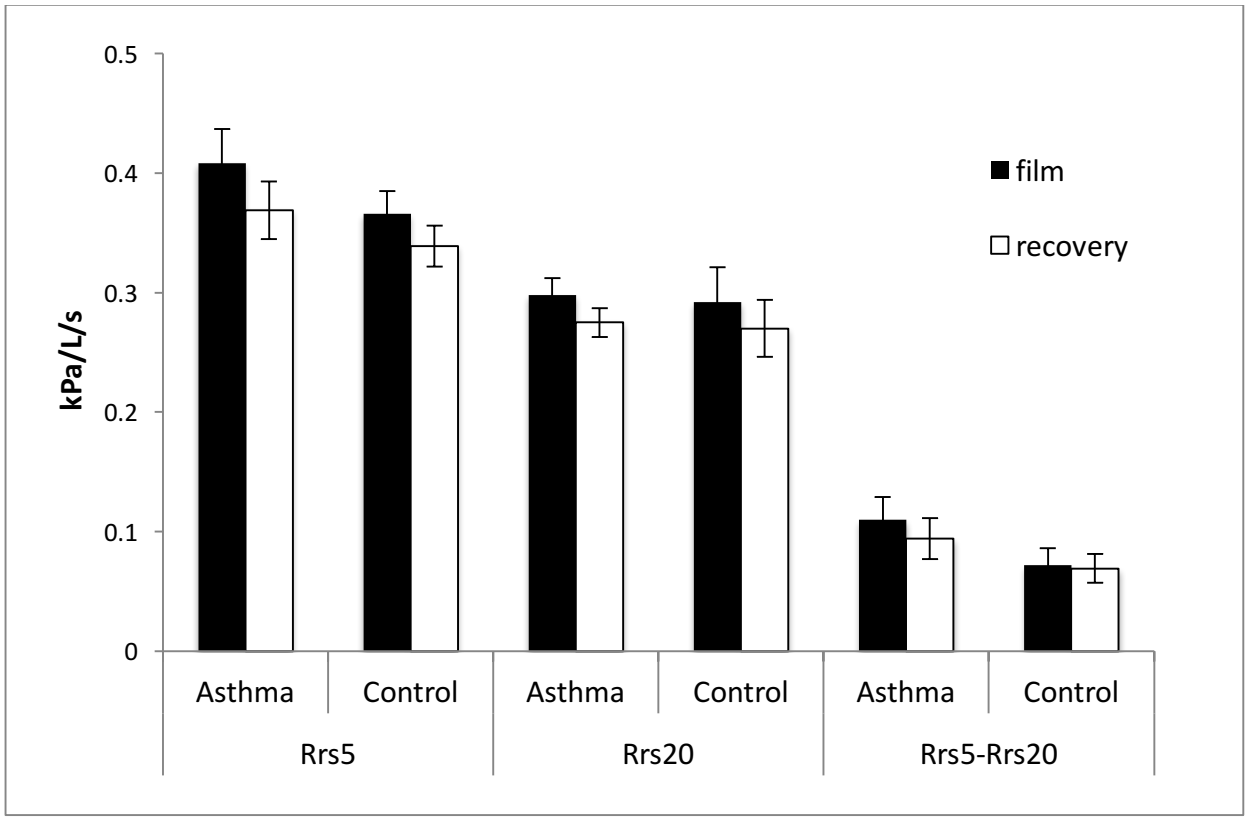
Figure captions

Figure 1. Total (Rr_{s5}), central (R_{rs20}), and peripheral (panel R_{rs5-20}) respiratory resistance for during film clip and recovery periods.

Figure 2. Upper panel: Changes in total respiratory resistance (R_{rs5}) across blocks of three films. Lower panel: Changes in central airway resistance (R_{rs20}) across three films within blocks.

Figure 1.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Asthma
Control
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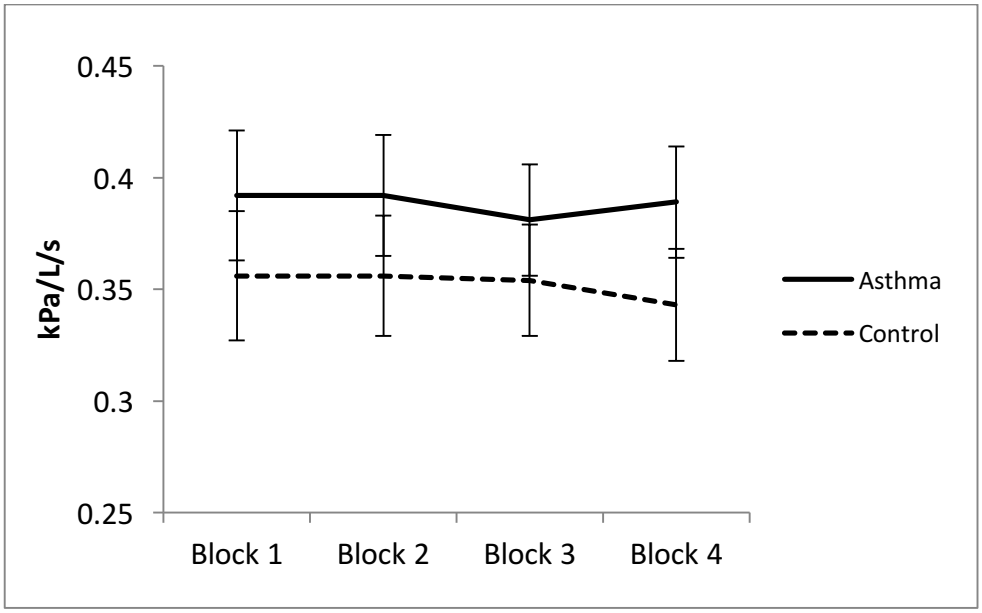
Rrs5-Rrs20

Figure 2.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Asthma
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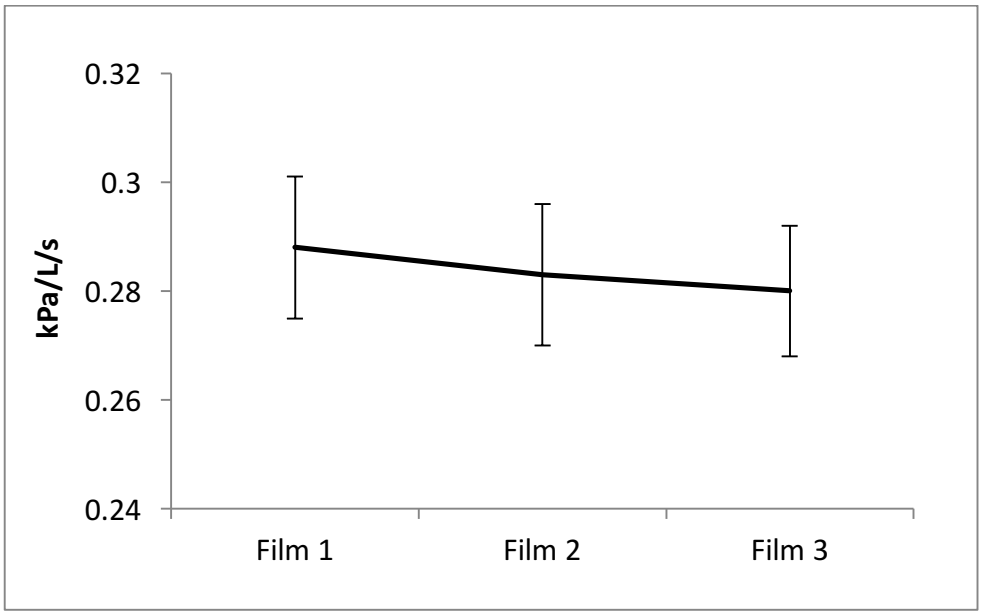
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